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Turbulent momentum transport and intrinsic rotation in tokamaks[1]

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A key physics issue for magnetic confinement fusion is the presence of high levels of turbulent particle and energy transport in magnetized plasmas. This transport is detrimental to fusion because it significantly lowers the plasma density and temperature, both of which must be kept high to increase fusion energy yield. Sheared flows have been shown to strongly reduce this plasma turbulent transport. Many current fusion experiments induce sheared flows by injecting beams of neutral particles, which make the plasma differentially rotate. However, this external momentum injection will be much less effective in the large, dense plasmas that may be required for a fusion reactor. A number of recent fusion experiments have measured significant differential rotation even without external momentum injection. This 'intrinsic' rotation is a result of the rearrangement of momentum within the plasma. Since this rotation may determine the extent to which turbulent transport is suppressed, it is critical for the community to understand how momentum transport produces intrinsic rotation profiles. This is challenging, as intrinsic rotation exhibits a complex phenomenology that defies simple empirical scalings or heuristic models. This talk gives a brief overview of the intrinsic rotation phenomenology and elucidates features that any viable model for intrinsic rotation must contain. We propose a fully self-consistent, first-principles model for intrinsic rotation, which is based on an asymptotic expansion in the smallness of the turbulence fluctuation frequency relative to the ion Larmor frequency (known as gyrokinetics). Stringent conditions are placed on this model by a symmetry of the gyrokinetic equations. This model has been implemented in the gyrokinetic turbulence code GS2, from which we present simulation results on turbulent momentum transport. Various physical mechanisms that contribute to the momentum transport are studied to determine their dependences on key plasma parameters and their relative importance for generating intrinsic rotation.

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